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RESEARCH ARTICLE

Determining the level of cervical radiculopathy: Agreement between visual inspection of pain drawings and magnetic resonance imaging

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Abstract

Background and Aims: Pain drawings are commonly used in the clinical assessment of people with cervical radiculopathy. This study aimed to assess (1) the agreement of clinical interpretation of pain drawings and MRI findings in identifying the affected level of cervical radiculopathy, (2) the agreement of these predictions based on the pain drawing among four clinicians from two different professions (i.e., physiotherapy and surgery) and (3) the topographical pain distribution of people presenting with cervical radiculopathy (C4–C7).

Methods: Ninety-eight pain drawings were obtained from a baseline assessment of participants in a randomized clinical trial, in which single-level cervical radiculopathy was determined using MRI. Four experienced clinicians independently rated each pain drawing, attributing the pain distribution to a single nerve root (C4–C7). A post hoc analysis was performed to assess agreement.

Outcome measures: Percentage agreement and kappa values were used to assess the level of agreement. Topographic pain frequency maps were created for each cervical radiculopathy level as determined by MRI.

Results: The radiculopathy level determined from the pain drawings showed poor overall agreement with MRI (mean = 35.7%, $K = -0.007$ to 0.139). The inter-clinician agreement ranged from fair to moderate ($K = 0.212$–0.446). Topographic frequency maps revealed that pain distributions were widespread and overlapped markedly between patients presenting with different levels cervical radiculopathy.

Conclusion: This study revealed a lack of agreement between the segmental level affected determined from the patient's pain drawing and the affected level as identified on MRI. The large overlap of pain and non-dermatomal distribution of pain reported by patients likely contributed to this result.

KEYWORDS
cervical radiculopathy, clinical agreement study, MRI, pain distribution, pain drawing

INTRODUCTION

Cervical radiculopathy refers to a group of signs and symptoms related to compression or irritation of the cervical spinal nerve root.[1] Patients most commonly present sensory changes (such as sensory loss or gain), motor abnormalities (such as reduced strength and reflexes), and unilateral neck–arm pain.[2] The age-adjusted incidence of radiculopathy is 83.2 per 100,000 individuals, increasing to 202.9 for those aged 50–54.[3] Its clinical course is typically self-limiting but long-lasting.[4] About 55% of individuals experience most of the improvements in symptoms and function within 12 months[4] and 83% recover completely within 2–3 years.[5] Conservative management should be offered if possible for at least 6 weeks, while surgical intervention should be considered only for individuals with persistent symptoms and functional limitation.[1,6]

Among medical imaging modalities, magnetic resonance imaging (MRI) is considered the first-choice method of assessment.[7] Its soft tissue contrast and the good spatial resolution provide the possibility to evaluate the presence of nerve root impingements. A prospective study comparing contrast-enhanced computed tomography and MRI in patients with cervical radiculopathy supported their accuracy for both the severity and cause of foraminal stenosis.[8] However, the attribution of symptoms to specific nerve roots using MRI images can be challenging when considering that spondylotic and discogenic changes can be seen in asymptomatic individuals, especially with increasing age.[9–11] As such, imaging is typically used in conjunction with a detailed history and a combination of physical tests to determine the affected nerve root.[12]

A pain drawing is commonly completed by patients so that they can easily communicate the location and distribution of their pain; clinicians then interpret these drawings by visual inspection. Only two studies have sought to assess the utility of pain drawing interpretation in the diagnosis of cervical radicular pain.[13,14] No studies have investigated the agreement in the identification of the affected nerve roots between pain drawings and MRI in patients with cervical radiculopathy.

This study investigated the agreement between the level of cervical radiculopathy derived from pain drawings and MRI and agreement between four clinicians on the level of cervical radiculopathy derived from pain drawings. Additionally, topographical pain frequency maps were created for people presenting with C4–C7 cervical radiculopathy to illustrate the distribution of their pain.

MATERIALS AND METHODS

This study was a secondary analysis of baseline data collected from patients with MRI-identified cervical radiculopathy forming part of a randomized control trial (RCT) designed to compare the efficacy of two postoperative rehabilitation interventions.[15] At the time of the data collection, all patients were scheduled for either anterior surgical decompression or posterior foraminotomy/laminotomy. Here, the data from 98 patients with single-level cervical radiculopathy were analyzed. The diagnosis was performed by a neurosurgeon by considering the clinical information and MRI radiological findings. The MRI of the cervical spine included the following sequences: T1-weighted sagittal, T2-weighted sagittal, and T2-weighted transverse. A radiologist graded the nerve root compression by visual rating and a provided a written report for each patient. Here, the data from 98 patients with single-level cervical radiculopathy were analyzed. Participants were recruited from four Neurosurgery clinics across the south of Sweden between 2009 and 2012. The study was approved by the regional ethical review board in Linköping and conducted in accordance with the Declaration of Helsinki.

Participants

As described in the original report,[15] participants were considered for the study if they were aged between 18 and 70 years, with cervical disc disease and cervical radiculopathy diagnosed on MRI. Participants had to have a minimum of a 2-month history of persistent pain. Exclusion criteria included past or current myelopathy, cervical spine fracture or luxation, past surgery to the cervical column, any malignancy or spinal infection. Patients were also excluded if they reported any history of systematic disease, had a severe psychiatric disorder, drug abuse, or were unable to speak Swedish. For the purposes of the current study, people with multi-level radiculopathy were excluded.

At baseline, the participants completed a series of questionnaires detailing their symptoms (such as intensity and frequency), as well as perceived impact on quality of life. Pain drawings were included among the questionnaires. The clinicians who rated the pain drawings did not have access to information from the questionnaires. Their decision regarding the level of cervical radiculopathy was based solely on the pain drawings.

Questionnaires

Pain intensity

Pain intensity was measured using a visual analog scale (VAS) anchored by 0 = no pain, and 100 = worst imaginable pain. Patients were asked to complete a VAS for average neck pain, arm pain, and headache intensities over the last month.

Disability

The Neck Disability Index (NDI) was used to assess pain-related disability specifically related to neck pain.[16] The NDI consists of 10 items grading neck disability from 0 to 50 which is then expressed as a percentage (0%–100%) with a higher score representing a higher level of disability. The NDI is widely used and is a reliable (intraclass correlation coefficient up to 0.98) and valid measurement of disability in neck pain disorders including cervical radiculopathy.[17,18]

Psychosocial factors and psychosomatic distress

Depression was assessed with the Zung Self-Rating Depression Scale which assesses affective, psychological, and somatic symptoms associated with depression; scores range between 20 and 80 and are classified as normal (<50), mild depression (50–59), moderate to marked major depression (60–69), and severe to extreme major depression (>70).

Somatic anxiety was evaluated with the Modified Somatic Perception Questionnaire (MSPQ) which included 22 items and scores of 0–39; higher scores were indicative of a higher level of somatic anxiety.

The participants' confidence in their ability to perform activities despite their pain was evaluated using the Self-Efficacy Scale (SES). SES is a reliable instrument consisting of 20 different physical and psychosocial activity items (from 0 = not confident at all, to 10 = very confident), thus generating a total score from 0 to 200.[19]

General health

Health-related quality of life was quantified using the EuroQol Five Dimension Scale (EQ-5D), in which 243 possible health states are converted to a single index value (−0.594 to 1, where 1 is perfect health) and the EuroQol VAS (0–100 representing worst to best imaginable health state, respectively).[20]

Pain drawings

The body charts used for the pain drawings consisted of two androgynous A4 size body templates, displaying the ventral and dorsal views of the body. Participants were asked to shade with a pencil on these templates every area that they felt pain, independent of the pain severity. The pain drawings were then scanned and digitalised using the method outlined in a previous investigation.[21] Transparent templates were laid over the digitized body charts, allowing the participants' drawings to be encircled using the "region of interest" tool (Inkscape version 0.48). A custom-developed MATLAB program computed the pain extent, based on the total number of shaded pixels within the body chart perimeter. The number of shaded pixels were then expressed as a percentage of the total area of each template (ventral: 191823 pixels, dorsal: 189328 pixels). This method has been shown to be reliable for documenting the spatial extent and location of pain in people with chronic pain.[22]

The pain drawing from each of the 98 participants was independently assessed by four clinicians: two experienced musculoskeletal physiotherapists (17 and 49 years of experience, respectively) and two experienced spine surgeons (22 and 30 years of experience, respectively). Clinicians were informed that all 98 patients had been diagnosed with a cervical radiculopathy at just one of four cervical levels, C4–C7, and were asked to identify the level of nerve root involvement based on the pain drawing. No additional clinical data were provided and clinicians were not limited by time. Each clinician received:

1. An electronic page-numbered portable document format (PDF) file containing the pain drawings (dorsal and ventral view) of all 98 participants. In addition to the visual distribution of pain, a summary of the total area of pain was provided, quantified both as number of pixels and as a percentage of the total body area (Figure 1). The body charts were anonymised, labeled with unique study ID numbers and were presented in random order to each clinician.
2. A pre-formatted spreadsheet (Microsoft Excel format) was provided which contained two pre-populated columns (page numbers [1–98] and study ID numbers) and one additional column in which the clinicians could attribute the pain distribution to a single nerve root from a drop-down menu with four options (i.e., C4, C5, C6, or C7). A "I don't know" option was not provided, so clinicians were required to choose one of these four options.

Statistical analysis

Data were transferred into an Excel file, with participants separated into groups based on the MRI-verified spinal level. Response agreement with MRI data was coded manually for each clinician. Agreement between the clinicians was also assessed. Blank or invalid responses were coded as a no-match. Percentage agreement and the kappa statistic were used to assess agreement between the clinicians and the MRI-verified level and to assess inter-clinician agreement. Significance of kappa values were adopted from benchmarks set by Landis and Koch with kappa values <0.00 indicative of no agreement, 0.00–0.20 representing slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–1.00 almost perfect agreement.[23]

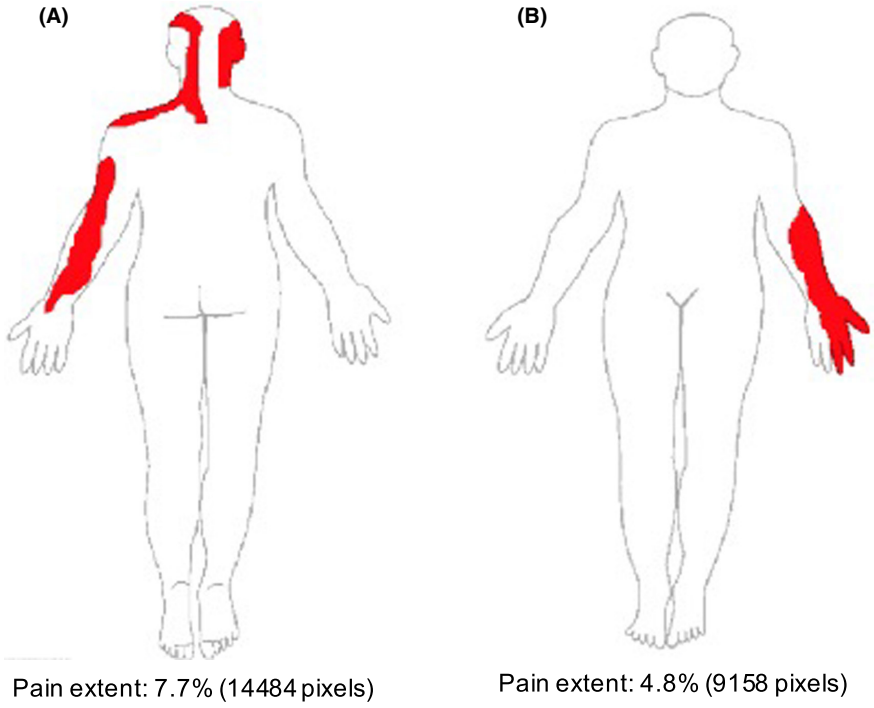

FIGURE 1 Two representative pain drawing provided to the clinicians, with patient's pain displayed in red. (A) ventral body chart and (B) dorsal body chart

TABLE 1 Participant demographics and overall health status considering pain, work, disability, general health, and psychological factors for each group defined by the nerve root affected

Variable	C4 (*n* = 4)	C5 (*n* = 7)	C6 (*n* = 54)	C7 (*n* = 33)
Demographics				
Age, mean (SD)	51.2 (14.2)	53.2 (6.3)	45.8 (7.7)	49.6 (7.4)
Height, mean (SD)	182.7 (9.6)	171.6 (11.6)	172.3 (8.1)	174.6 (8.4)
Weight, mean (SD)	89.2 (17.3)	77.5 (16.8)	78.4 (16.3)	84.4 (14.6)
Gender, male *n* (%)	4 (100)	4 (57)	22 (40.7)	20 (60.6)
Pain mean (SD)				
VAS neck (0–100)	58.0 (44.0)	52.4 (29.9)	57.0 (23.4)	53.7 (25.5)
VAS arm (0–100)	26.0 (22.4)	52.0 (36.2)	56.7 (28.3)	51.2 (27.2)
VAS headache (0–100)	22.2 (38.5)	22.2 (22.3)	28.0 (29.6)	24.1 (30.3)
Disability mean (SD)				
NDI (0%–100%)	48.0 (25.1)	42.2 (18.4)	42.6 (14.2)	45.3 (15.1)
General health and psychological aspects mean (SD)				
EQ-5D (−0.594 to 1)	0.2 (0.3)	0.5 (0.3)	0.4 (0.3)	0.3 (0.2)
ZUNG (20–80)	44.7 (17.5)	39.8 (7.5)	43.0 (8.1)	44.7 (9.1)
MSPQ (0–39)	9.2 (5.1)	6.1 (4.3)	8.2 (4.8)	8.2 (6.0)
SES (0–200)	111.2 (57.8)	133.8 (38.8)	127.0 (39.4)	105.8 (41.7)

Abbreviations: EQ-5D, EuroQol-5D health questionnaire; MSPQ, modified somatic perception questionnaire; NDI, neck disability index; SES, self efficacy scale; VAS, visual analog scale; WAI, work ability index; ZUNG, self-rating depression scale.

The available pain drawings were grouped based on the segmental level affected according to the MRI diagnosis, and then superimposed to obtain topographical pain frequency maps of the perceived pain. A color scale was used to report absolute numbers and percentages of subjects who reported pain on the specific areas of the body charts.

RESULTS

Of the 98 participants with a single-level radiculopathy in the study, 50 were women. Across all participants, ages ranged between 22 and 66 years, with a mean (SD) of 48.0 (8.0) years. Table 1 presents the characteristics

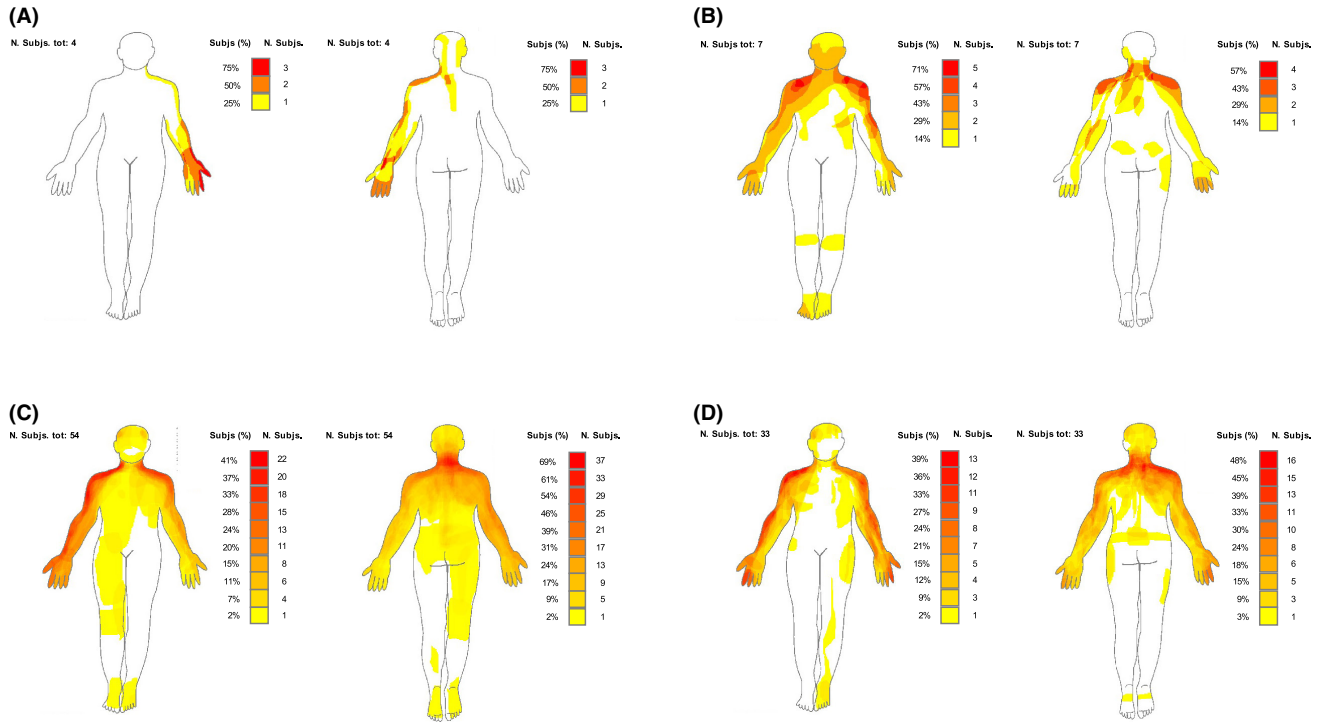

FIGURE 2 Topographic pain frequency maps generated across all participants presenting with (A) C4 radiculopathy ($n = 4$), (B) C5 radiculopathy ($n = 7$), (C) C6 radiculopathy ($n = 54$) and (D) C7 radiculopathy ($n = 33$). Darker colors represent higher frequency of reported areas. Subjs, subjects

of the patients according to the questionnaire data. The pain frequency maps for the participants grouped according to the cervical radiculopathy level affected are presented in Figure 2.

All clinicians submitted a minimum of 95 valid responses of the total 98. Blank answers (6 of 392 total) and spinal levels outside of those permitted (2 of 392) were excluded from the analysis.

Percentage agreement

Overall, the clinicians' responses correctly corresponded with the MRI results on 35.7% (6.1%). As can be observed in Table 2, there was very little agreement with the MRI-verified C4 and C5 levels by any clinician. The average agreement for C6 was 34.7 (5.3)% and for C7 it was 47.7 (18.2)%.

The two physiotherapists were able to correctly evaluate the affected level 37.2% of the time vs 34.1% for the surgeons. Both professions were most successful in identifying the lower cervical spinal segments (Table 2).

Cohen's kappa statistic

Cohen's Kappa statistic (K) was run in order to assess the agreement between each of the four clinicians and MRI-verified level. There was no agreement ($K = -0.063$ to 0.139) between the clinicians' opinion of the level affected based on the pain drawing and the spinal level identified by MRI, beyond that expected by chance. The inter-clinician analysis showed K values from 0.281 to 0.561 indicating fair to moderate agreement (Table 3).

DISCUSSION

This study revealed very poor overall agreement between clinical interpretation of the level affected based on the patient's pain drawing and the affected cervical level as identified on MRI. However, there was fair-to-moderate agreement among clinicians in their decisions made from the pain drawings. The topographic pain frequency maps generated did not reveal a specific pattern of pain location for each level of cervical radiculopathy investigated. Overlapping pain distributions were evident, particularly for the C6 and C7 pain frequency maps, and this likely explains the difficulty in interpreting the pain drawings. Widespread pain involving lower trunk and lower limbs was also present albeit in a limited number of patients (Figure 2).

Agreement between pain drawing and MRI

The poor overall percentage of agreement between the MRI-identified level and the clinician identified levels from the pain drawings was below what we had expected. The highest concordance was noted to be in the lower

TABLE 2 Percentage of agreement between initial interpretation of pain drawings by physiotherapists or spine surgeons and MRI-identified level

	Agreement (%) with MRI-identified level				
Raters	**Overall (n = 98)**	**C4 (n = 4)**	**C5 (n = 7)**	**C6 (n = 54)**	**C7 (n = 33)**
PT1	32.7	0	14.4	33.3	39.4
PT2	41.8	0	0	31.5	72.7
S1	39.8	0	0	42.6	48.5
S2	28.6	0	14.3	31.4	30.3

Abbreviations: PT, physiotherapist; S, spine.

TABLE 3 Kappa agreement between each of the four clinicians and MRI-identified level of nerve root involvement and kappa agreement within and between each profession

Raters	**Kappa**	***p* Values**
MRI vs PT1	−0.007	0.912
MRI vs PT2	0.139	0.030*
MRI vs S1	−0.013	0.870
MRI vs S2	−0.063	0.326
PT1 vs PT2	0.212	0.001*
S1 vs S2	0.446	0.000*
PT1 vs S1	0.417	0.000*
PT1 vs S2	0.413	0.000*
PT2 vs S1	0.561	0.000*
PT2 vs S2	0.281	0.000*

Abbreviations: PT, physiotherapist; S, spine surgeon.
*Significant (p<0.05).

spinal segments, that is, C7, with 47.7 (18.2)% (range 30.3%–72.7%) of pain drawings correctly identified, followed by C6 with 34.7 (59.3)% (range 31.5%–42.6%) correctly identified. Collectively, these two levels comprised the majority of our patient cohort with 33 (C7) and 54 (C6) patients in each. The C4 and C5 spinal segments, comprising 11 patients, showed little to no agreement (range 0%–14.3%).

Epidemiological studies are quite scarce, however the disproportionate division of the affected segmental level is reflective of the pattern seen in a demographically similar population.[1] The reason for the higher incidence at C6 and C7 may be attributed to the progressive decrease in foraminal space toward the C6–C7 level, rendering the lower segmental nerve roots more susceptible to spondolytic or discogenic changes.[3] This is also supported by recent investigation that highlighted that cervical foraminal stenosis is higher at lower cervical segments.[24] If healthcare professionals encounter individuals with C6 or C7 spinal nerve lesions more often in practice, it follows that they may use this experience to inform their reasoning. When chance is taken into consideration using the kappa statistic, no agreement was observed across all professionals, with K values ranging from −0.063 to 0.139.[23] For three of the four clinicians, evaluations were less accurate than what you would expect to see by chance.

Our findings are in line with a study conducted in 61 patients with long-standing nerve root symptoms, which showed a disagreement between the MRI visible nerve involvement and the presence of nerve involvement identified by a physical examination and pain drawing.[13] The authors questioned the notion that the MRI should be considered as the reference diagnostic method for a patient with suspected radiculopathy; assuming an underestimation of the nerve involvement prevalence by MRI and the validity of the proposed clinical examination.

Inter-clinician agreement

Within the context of this study, we have seen fair to moderate concordance between clinicians with the two spine surgeons showing slightly higher agreement (K = 0.446) when compared to physiotherapists (K = 0.212). Between each profession, agreement ranged from K = 0.281 to 0.561, remaining fair to moderate agreement. However, as there were only two individuals representing each profession, any statement about different approaches or performance in evaluating the pain drawings would be speculative. The observed greater agreement between clinicians than against the MRI might reflect some elements implicated in the visual inspection of the pain drawing or in the underlying reasoning of the clinicians. First, the reduced variability of the pain drawings in terms of anatomical areas shaded, as revealed by the topographical pain frequency maps, may have polarized the clinicians' assessment toward some cervical levels. A high percentage of pain drawings depicted, at least partially, the medial aspect of the upper limbs and the fingers. Assuming that the classic dermatomal distributions of pain were considered during evaluation and that C8 was not an option, a situation may have arisen where clinicians only had to choose between C6 and C7. Again, epidemiological data may have had some effect on the clinicians' scores. As C6 and C7 radiculopathies are more prevalent in practice, it is likely that when uncertain, clinicians were more likely to choose one of those two segmental levels. Although the kappa

statistic takes chance into consideration, the scores available were potentially biased toward the lower two segments. The above complements existing literature which shows moderate reproducibility of neurological upper limb physical assessment strategies.[25]

Dermatomal inconsistency

The pain patterns observed differ from what would be typically expected according to classic dermatomal distributions of pain.[26,27] More recently, new dermatomal maps were developed in order to identify the most consistent dermatomal areas.[28,29] Lee and colleagues suggest a C4 distribution which extends posteriorly down the spinous processes of the cervical vertebrae, across the spine of the scapula and into the acromion process.[28] Anteriorly, the most consistency is found from the midpoint of the clavicle extending toward the deltoid. They do state however, that there is significant variability and overlap. However, this pattern was not common for the participants in the current study since the topographic pain frequency map of those with the C4 nerve root affected show the most commonly reported areas to be distal, extending into the thumb and fingers (Figure 2A). As this distribution is more commonly representative of a C6/7 lesion, this could potentially explain the low agreement found by the clinicians. A previous study also concluded that pain attributed to the cervical nerve roots was non-dermatomal in 69.7% of cases.[30] Unlike our study, however, they found C4 to be the most representative, with 60% of symptoms falling within the expected dermatomal distribution (sensitivity 0.60, specificity 0.72). It is unclear from that report which dermatomal maps were utilized in order to make this distinction, and similarly, sample size (n = 5) limits generalizability of their findings.

Tampin and collaborators found that individuals with C6 radiculopathy show a somatosensory profile which is distinct to that of individuals with non-specific neck/arm pain and fibromyalgia and interestingly, areas of maximal pain reported by these patients included upper trapezius (n = 4), paravertebral thoracic spine (n = 7), upper arm lateral (n = 5), and paravertebral cervical spine (n = 2).[31] These areas do not correspond to the traditional dermatomal distribution, but are supported by our findings (Figure 2). Notably, our pain frequency maps highlight pain patterns similar to that described in a clinical commentary by Gifford, for patients with acute low cervical root irritation.[32] Similarities can be also detected with maps of the cervical nerve roots obtained using an intraoperative stimulation technique.[33]

Similar conclusions were also recently reported by Furman and Johnson.[34] The level-specific pain distributions evoked in patients with lumbar radicular pain during the transforaminal epidural injections were not predicted by classical dermatomal maps.[34] Further investigations, using pain drawings, with a larger sample and stratification by nerve roots could reveal clinically relevant information. Additionally, the application of advanced methods for pain drawing analysis, for example, principal component analysis, has great potential in analyzing the complex pattern of pain location extracted from the pain drawings.[35]

Clinical features and psychosocial characteristics of the study sample

Participants in this study were scheduled to have surgery and therefore people with mild/moderate radicular symptoms were not considered. Although not tested, it is possible that some of the participants presented with central sensitization which could explain the sensation of pain outside of the classic dermatomal pattern which would have contributed to the difficulty in identifying the specific nerve root involved.

The psychological profile of our participants acknowledges the multidimensional nature of their pain. The average Neck Disability Index score of the current sample was moderate to high at 43 (8)%, with additional self-reported questionnaire data showing that 65 of the 98 participants feel their pain "Always," and 40 consider their life with the pain to be "Miserable." This is consistent with previous study cohorts.[31,36] Their Work Ability Index score was low–moderate, at 28 (9) points.

Previous studies have shown an association between psychosocial features and the extent of pain reported on a pain drawing in other patient populations such as whiplash associated disorders,[37] neck pain,[38] and osteoarthritis[39] with larger pain areas correlated with poorer psychological health. It is possible that an amplification of the perceived pain area was present for some of the participants in the current study adding to the difficulty of identifying the nerve root level affected.

Overall, our findings refer to the pivotal importance of multicomponent evaluation of patients with suspected radiculopathy. This is in line with a recent systematic review suggesting the use of nine different classification criteria for future trials involving people with cervical radiculopathy.[40] High-quality evidence for a singular classification criterion is not currently available and experts agree that self-reported symptoms and objective findings should be clustered during the diagnostic procedures.[41] Pain drawings have the potential to improve the evaluation of neuropathic pain,[42] especially when integrated with the medical imaging and provocative tests.

Limitations

The small sample size of the two upper spinal cohorts (C4 and C5) was a limitation of the study and likely contributed to the poor agreement at these levels. That said, the

population distribution is reflective of the prevalence of radiculopathy at different spinal levels. As this study excluded patient interaction, and physical examination, it is not a representation of overall ability to assess. Bertilson and colleagues showed that during the subjective interview 60%–72% of patients made additions to their initial pain drawing.[13] This, as well as the possibility to report the pain severity in the various anatomical areas, may have affected our findings. Also, the clinicians interpreting the pain drawings were from four different institutions based in three countries and may not necessarily be representative of their professions. Lastly, the availability of additional diagnostic procedures such as nerve root blocks or electromyography would have strengthened the study.

CONCLUSION

Pain presentations of patients with single-level cervical radiculopathies proved to be very different to classic dermatomal distributions of pain. There was poor overall agreement between the clinicians' interpretation of the cervical level affected based on pain drawings and that identified on MRI. Clinicians showed some agreement in rating the nerve root level affected based on a pain drawing alone. Future investigations should explore the possible integration of pain drawing in diagnostic procedures for radicular pain.

CONFLICT OF INTEREST

No conflict of interest exists in the submission of this manuscript, and the manuscript is approved by all authors for publication.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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